Improving Water Vapor Continuum Absorption and Its Impact on a GCM Simulation

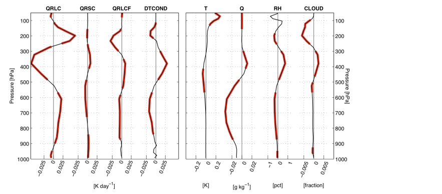
Research Highlight

Improving the accuracy in radiative transfer codes used within general circulation models (GCMs) is an important climate research priority in the U.S. Department of Energy. Our understanding of the gaseous absorption in the mid-infrared (i.e., from 3–16 µm), which underlies these radiation codes, has undergone many important improvements due to the well-characterized radiation measurements by the atmospheric emitted radiance interferometer (AERI), microwave radiometer, and other instruments at the ARM sites. However, there has been a relative lack of attention paid to radiation at the longer wavelengths of the far-infrared region (i.e., 16–100 µm). This lack of attention was due to two things: (a) the unavailability of accurate spectrally resolved infrared measurements in the far-IR due to limitations in detector technology and (b) the opacity of the atmosphere in the far-IR at most surface locations due to strong water vapor absorption, thereby requiring that the observations be made in locations where the precipitable water vapor (PWV) is very low. For these very dry conditions, the standard ARM microwave radiometers do not have adequate sensitivity to derive accurate values of precipitable water vapor (PWV), a necessity for analyzing far-IR measurements, so new microwave radiometers also had to be designed and built.

Advances in far-infrared and microwave measurement technologies led to the conduction of the Radiative Heating in Underexplored Bands Campaigns (RHUBC). There were two phases to RHUBC: the first occurred at the ARM site in Barrow, Alaska, in 2007, while the second was conducted on a mountain, Cerro Toco, in northern Chile in 2009. The results from RHUBC-I led to a number of improvements in our understanding of far-infrared gaseous absorption, including a substantial change (factor of 2) in the strength of modeled water vapor continuum absorption, as well as changes to the widths of many water vapor absorption lines in the far-IR. These changes to the underlying spectroscopy in infrared radiative transfer codes resulted in significant changes in the calculation of longwave heating rates for a clear sky atmosphere, with the updated code providing more heating of the upper troposphere relative to the older version of the radiative transfer code.

A radiative transfer code with updated water vapor continuum absorption that reflected the results of RHUBC-I was implemented into the Community Earth System Model (CESM v1), and a 20-year simulation was conducted with both the original radiation treatment and the improved version. The results from these two CESM simulations demonstrated both radiative and dynamic differences, including changes in the atmospheric temperature and humidity profiles in both the middle and upper troposphere. These changes affected the relative humidity profile, leading to a change in the cloud amount in both the middle and upper troposphere. The changes in the cloud amount had a dual impact, modifying both the longwave cloud radiative forcing and the heating rate profile associated with moist convective processes (e.g., latent heating), both of which partially offset the changes in the radiative heating due to the changed water vapor absorption. The magnitude of the changes to the mean temperature, humidity, and cloud profiles, as well as the resulting influence on the diabatic heating within the model, showed a latitudinal dependence, with the largest impacts in the tropics and subtropics.

The RHUBC-I data set and subsequent analysis resulted in an improved water vapor continuum absorption model in the far-IR that has less uncertainty than the previous model. Updating the infrared radiative transfer code in CESM to account for this change resulted in both a dynamic and radiative response in a multi-decade model simulation. While the impact of this change in the radiative transfer code has a significant impact on this CESM simulation, the behavior of other GCMs may be quite



The mean difference profiles (experiment minus control) for clear-sky longwave radiative heating (QRLC); shortwave clear-sky radiative heating (QRSC); the longwave cloud radiative forcing (QRLCF); the precipitation physics tendency (DTCOND); temperature; specific humidity; relative humidity; and cloud fraction amount profiles. These profiles are averaged from 15 degS to 15 degN over the 20-year simulation period. Bolded regions are statistically significant.

different due to different parameterizations and how the interactions between the dynamics and physics are embodied within these other GCMs.

Reference(s)

Turner DD, A Merrelli, D Vimont, and EJ Mlawer. 2012. "Impact of modifying the longwave water vapor continuum absorption model on community Earth system model simulations." Journal of Geophysical Research, 117, D04106, doi:10.1029/2011JD016440.

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Cloud Life Cycle